33 Lib – analog of gamma Equ

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ABSTRACT

In this paper we study periodic variability of the magnetic field in the Ap star 33 Lib. We found that its most probable period equals 83.5 years. There exist also possible shorter periods: 11.036 days, 7.649 days and 4.690 days. Analysis of the magnetic behavior of 33 Lib allows us to conclude, that the star shows the second longest period the slow rotator gamma Equ, the latter star with the period of 97 years.

Key words: *Stars: chemically peculiar – Stars: magnetic fields – Stars: individual: 33 Lib*

1. Introduction

Magnetic field of chemically peculiar Ap star 33 Lib (HD 137949) was discovered by H.W. Babcock on June 13, 1957 (Babcock 1958). Variability of the longitudinal component B_e of 33 Lib was first studied in 1971 (van den Heuvel 1971). Period of the magnetic variability was estimated there, $P_{mag} \approx 18.4$, based on a low number of measurements. Furthermore, Wolff (1975) also found periods 23.26 days and 7.194 days. from observations of the magnetic field. Most recent assessment of the magnetic period of 33 Lib was published by Romanyuk et al. (2014), who determined $P_{mag} = 7.0187$ days. Authors determined also the amplitude of B_e variability equal 650 G with the average strength of the longitudinal field, $\overline{B_e} = 1528$ G.

Attempts to detect light and color variations of the star did not lead to success (Wolff 1975; Deul & van Genderen 1983). Researchers noted lack of brightness variations within accuracy of 0.01 magnitude. For the first time weak photometric variability with the period of 4.8511 days was reported by Wraight et al. (2012). Data were obtained from by the satellite STEREO (NASA), see Eyles et al. (2007).

Kurtz (1982) discovered rapid photometric variability of 33 Lib with the period $P = 8.2721$ minutes. This finding reinforced the analogy with another well known magnetic Ap star Gamma Equ. The latter object exhibits strong global magnetic field, rapid photometric variability and long rotational period.

Ap stars provide a unique opportunity to assess unambiguously their rotational periods of and angles between the axis of rotation and the line of sight. Thanks to that we discovered amazing objects – "standing" or immobile stars with rotational periods equal to dozens or even hundreds of years old (Bychkov et al. 2006). Study of long-period variable is always associated with the obvious problem: it is difficult to obtain a homogeneous series of measurements over decades.

2. Analysis of observational data

Mathys et al. (1997) analysed variability of the longitudinal magnetic field of 33 Lib using measurements of B_e obtained during 36 years and concluded, that the likely rotational period of the star equals at least 75 years. Currently the available dataset contains more estimates of the magnetic field covering longer period of time - more than 50 years. Such an increase of time span allowed us to determine more realistic period of long term projected magnetic variations of 33 Lib, $P_{\mathrm{mag}} = 83.5 \pm 6.3$ years. The corresponding average magnetic phase curve was presented in Figure 1.

As can be seen, part of B_e estimates significantly deviates from the average (sine wave) phase curve. We attempted to find a higher order variations of the magnetic field. To do this, we have subtracted the average sine wave variation from the observed B_e time series and repeated spectral analysis of the prewhitened time series. Three new probable periods were found: 11.036, 7.649 and 4.690 days, which are listed in the order of descending probability 2.87σ, 2.80σ and 2.65σ, respectively. Phase curves corresponding to these periods are shown in Figs. 2–4.

Estimates of the longitudinal magnetic field B_e of 33 Lib were published in Babcock (1958), van den Heuvel (1971), Wolff (1975), Hubrig et al. (2004), Sachkov et al. (2011) and Romanyuk et al. (2014).

Sachkov et al. (2011) determined parameters and the chemical composition of the atmosphere of 33 Lib on the basis of high resolution spectroscopy and calculations of model atmospheres and synthetic spectra. Analysis of spectral energy distribution in the wavelength range 2000Å– 8000Åimplied $T_{\mathrm{eff}} = 7550 \pm 100$ K and $\log g = 3.9 \pm 0.1$. These parameters are parallax measured by satellite Hipparcos implied that the radius of 33 Lib equals $2.09 \pm 0.13 R_{\odot}$.
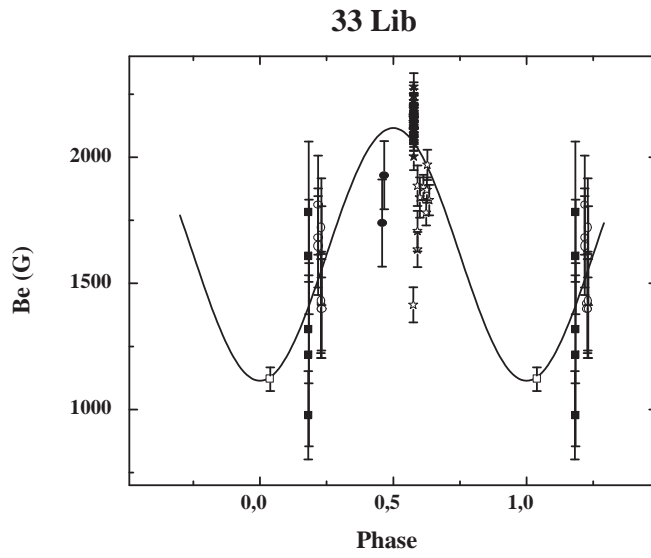
33 Lib

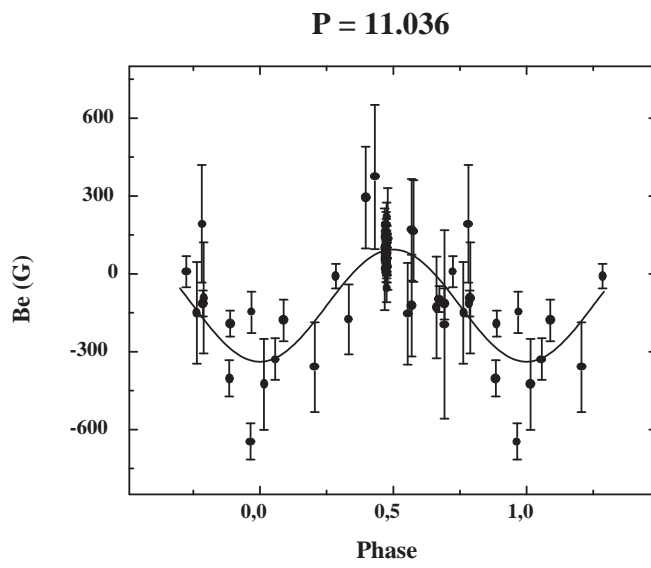Figure 1: Magnetic phase curve computed for the period 83.5 years.

P = 11.036

Figure 2: Magnetic phase curve for 33 Lib found from deviations for the period $P = 11.036$ days.
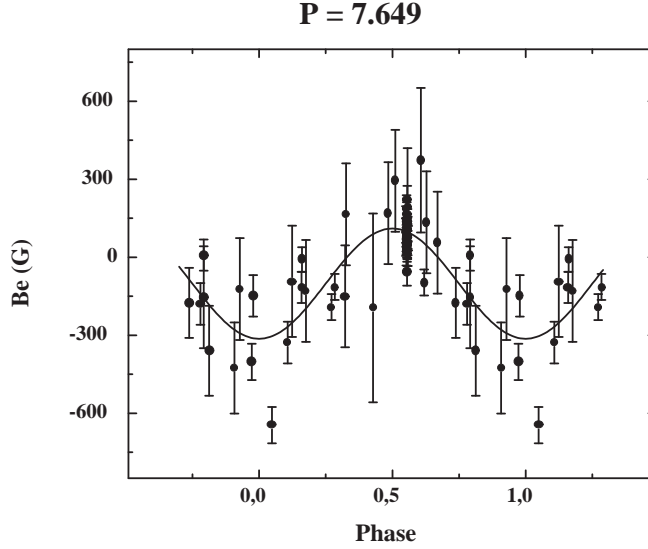
P = 7.649

Figure 3: Magnetic phase curve for 33 Lib found from deviations for the period $P = 7.649$ days.

3. Discussion

Currently there are determined the following observational parameters and quantitative results of spectral analysis of 33 Lib:

1. Projection of the equatorial rotational velocity on the line of sight, $V \sin i = 0.6$ km/s (Ryabchikova, T.A., personal communication). This value well correspond to our result, i.e. the period of the long term variations of the longitudinal magnetic field, $P_{mag} = 83.5$ years. Relation between the rotational (or magnetic) period and the velocity of axial rotation of the star on the equator is

$$V = 2\pi R/P = 1.3 \text{km/s}. \tag{1}$$

   Then, the resulting angle $i = 27°$.

2. Significant deviations of the magnetic field B_e points with respect to the average magnetic curve allowed us to assume, that there exist other possible periods of variability of unknown nature. Those periods equal 11.036, 7.649 and 4.690 days. It should be noted that the period of 7.649 reported here is close to the period of the longitudinal magnetic field variation of 7.0187 days, found by Romanyuk et al. (2014). Our suspected magnetic period of
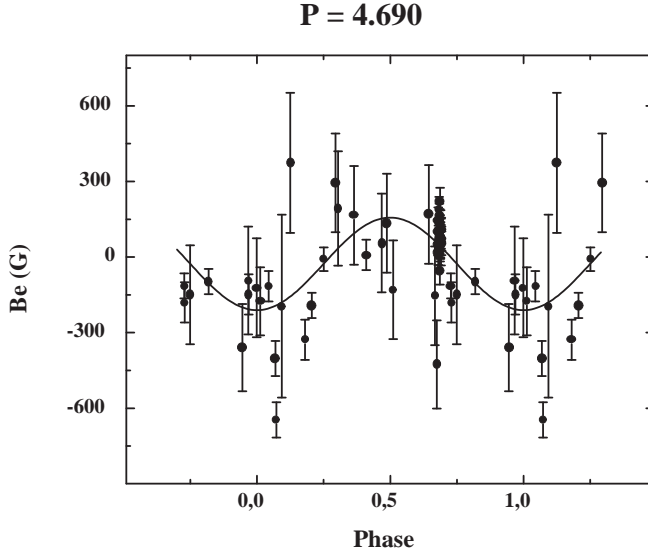
P = 4.690

Figure 4: Magnetic phase curve for 33 Lib found from deviations for the period $P = 4.690$ days.

4.690 days is close to the photometric period of 4.8511 days, independently found by Wraight et al. (2012). The most significant period of 11.036 days occurs first. The reasons for this short time variability are yet unknown.

4.   Concluding remarks

Actually there exists only 57 measurements of the longitudinal magnetic field B_e for 33 Lib, collected in time interval of about 50 years. Note the uneven distribution of B_e points in time, as well as the fact that the magnetic field estimates were obtained with various methods and by different instruments. All those circumstances make an analysis of available data difficult. We hope that in the near future to increase the duration of available B_e time series and the number of magnetic field observations. This would allow for more conclusive judgement regarding rotationaal period of the star 33 Lib.

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